Semantic Interoperability and Citizen/ Government Interaction

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Abstract

This paper presents an approach extending semantic similarity measures and Amit Sheth's work on Information Spaces to include non-declarative and non-formalized knowledge. This approach is an extension of concepts developed by Tim Berners-Lee and others for a next generation Internet known as the semantic web. Formalized information used by government agency staff will be stored in web accessible databases and shared when permitted over public access. Citizens will share non-formalized local knowledge in the same semantic web, called the Kentucky Water Information Network (KY-WIN). Diverse representations of formal and non-formalized knowledge will be made accessible through a gateway that builds and maintains semantic links to various sources. The gateway will be accessed through an interface that supports knowledge discovery and communication in a variety of ways to support multiple activities and grow with use. KY-WIN will help promote improved citizen/government interactions by creating a digital and civic infrastructure to integrate various knowledges and contribute to better democratic decision-making.
Keywords: semantic interoperability, knowledge, metadata, decision-making, ontology

1 Introduction

Since 1968 (Tomlinson, 1968), people around the world have widely adopted geographic information technologies for planning, forestry, facilities' management, research, and many other fields. Each GIS software product was developed however independently with little philosophical, scientific, or technical convergence. A user trained on one system would need to relearn a new system and procedures used with one software package could not be shared with people using another package. Interoperability is a recent concept which sets out to diminish these problems.

Interoperability has been particularly relevant for industry oriented activities including location-based services and web mapping services. And as other domains recognize its potential to resolve persistent problems of coordination, cooperation, sharing and integration (Goodchild et al., 1998), interoperability has gained in relevance for public administration. In interoperable environments, access to multiple agency databases in networked environments aids the support of cross-agency mandates.

Approaches to government agency interoperability invariably draw on activities in the private sector, particularly telecommunications, libraries and business practices (Smith and Poulter, 1999, Adam et al., 2000, Sheth, 1997). Industrial interoperability practice has advanced to a point where enterprise-level semantic webs are becoming commonplace. This paper draws directly on this concept and applies it to the improvement of citizen/government interactions. The semantic web is an Internet search engine that is more discriminating in its search results because of the use of semantics (Berners-Lee, 2001). In an enterprise environment, semantic webs provide capabilities to access and integrate information from a variety of sources including hypertext documents, xml, pictures, etc. (Sheth, 1998).

This paper describes an approach that extends ontology-based modeling of formalized knowledge (Ashenhurst, 1996, Fonseca, 2001), and adds the capability to support non-formalized and non-normalized knowledges, including front porch discussions about recent regional highway construction–narrative representations of knowledge in ethnographic terms. The integration of formalized and non-formalized knowledge is especially relevant for developing citizen information services that address endemic citizen/government interaction problems. The following anecdote illustrates different semantic and geographic knowledges that currently hinder interactions: Finding silt from a mining project running into a stream, a man contacted a government inspector who arrived sometime later. The inspector arrived with a sheaf of maps, looked the situation over, consulted his maps, and said to the man, "I'm sorry. I cannot take action. According to my map there is no stream there" (Hufford, 2001, p. 32).

Semantic interoperability provides concepts and technology to make maps interactive and to integrate various types of knowledge. The concepts presented in this paper were developed in the context of designing an information technology project to support citizen/government interaction centered on water-related environmental issues in Eastern Kentucky. This project has two main components: a) the development of KY Water Information Network (KY-WIN) Prototype, a virtual clearinghouse for data on water in Kentucky through b) participatory co-design of software that brings together citizens, high schools, experts and government officials. The virtual clearinghouse extends semantic interoperable information technology to provide access to multiple databases in the framework of knowledge discovery and interactive learning. During the proposed project, citizens, already affiliated with several citizen-orientated outreach programs and high schools, in Eastern Kentucky will contribute to and help guide the browser development. The description of technology will follow in later papers.

2 Semantic Similarity and Information Spaces

The underlying concepts that KY-WIN draws on originate with the semantic web. The semantic web is an extension of the internet that addresses fundamental problems current hypertext implementations are ill-equipped to meet. Search engines provide a way to find keywords, and possibly prioritize tens of thousands of "hits" by textual proximity analysis, but the semantic web provides ways to express meaning and link resources using ontologies. Semantic similarity and information spaces are key components of KY-WIN's semantic web.

2.1 Limits of Data/Metadata Model and the Semantic Web

Current limitations of data/metadata catalogs and clearinghouses are well known. If a person searches for geographic information using the FGDC clearinghouse network today they could only find data. Through more than ninety clearinghouses using standardized protocols, the NSDI provides an unparalleled geographic data infrastructure. This infrastructure is invaluable for many agencies and people around the country and has been copied in many countries around the world (Masser, 1998). It provides keyword level indexing tied to automatic keyword expansion to help facilitate many searches. The fundamental constraint is that most people expect to find information, not retrieve data (Rodriquez, 2000). The clearinghouse infrastructure can clearly be extended by semantic web concepts.

In terms of the central notion of geographic information integration, which is very close conceptually to semantic interoperability, previous monolithic GIS (Shepherd, 1991) have run into the fundamental problem that geospatial information varies according to representation and purpose (Lagrange, 1997). Large-scale database integration is not capable of resolving these differences. The semantic web offers a way to help address these problems by developing solutions that provide ontologies that define the relationships between terms and, when written in a common fashion, can be used to identify similar terms and relationships from multiple information sources.

Drawing on rich work on geospatial interoperability and the semantic web, KY-WIN takes the clearinghouse concept to the next stage of development. Associating behavior with the properties and behavior of information allows for specialized and generalized reasoning that exploits specific characteristics of the knowledge base (Wickler, 1995) and facilitates a more efficient use of information resources, it deploys computational techniques to assist in knowledge discovery and automate tasks that require access to multiple data repositories.

2.2 Extending Semantic Interoperability with Ontologies

Ontologies enable the dynamic association of information at the semantic level. Ontologies provide for ways to represent knowledge and resolve many differences. Even if it has the same feature name, and represents the same area, a wetland is not (always) the same wetland. In common language usage, the meanings of words can vary greatly (Harvey and Chrisman, 1998). The same wetland a hunter and biologist talk about may turn out to have completely different geographic extents, relationships, and functions. For formalized knowledge, semantics provides symbolic logic for representing such differences as relationships (Tarski, 1941; Tarski, 1952). Procedural representations of knowledge define the concept of ontology as “a logical theory which gives an explicit, partial account of a conceptualization” (Guarino, 1995). In an information system environment, we can extend this definition to apply to the representation of the domain knowledge of what is commonly referred to as an information community. “In information systems, ontologies capture the semantics of data sources and are a basis for information retrieval and integration” (Rodriquez, 2000). An ontology can be distinguished by terms/concepts, definitions, meanings, relationships, characteristics. Working with multiple geographic information sources requires an understanding of these differences, a very laborious process when dealing only with maps, data, and metadata. With ontologies, work with geospatial information can develop richer analytical tools and higher levels of interoperability and integration (Goodchild et al., 1999).

Previous semantic interoperability technologies have focused on integrating federated database systems, developing distributed information systems, and multimedia data management (Sheth, 1996, Bishr, 1998, Kashyap and Sheth, 1997). A widely accepted definition of the issues geospatial semantic interoperability faces is found in Bishr (1997). Echoing previous work in computer science, he distinguishes three aspects of interoperability: syntax, schema, and semantics, and continues to say that the problem of identifying semantically similar objects is the key problem for geospatial SI.

In most publications on semantic interoperability this issue is usually approached by lexical translation and semantic integration (Harvey et al., 1999). The most widely-used approach to helping users assess data meaning is to provide metadata, or data about data, for system users (Sheth, 1998). With the requisite skills, training, and experience, most people can learn to read the standardized metadata descriptions and find the answers to the majority of questions about the data. With metadata alone, however, it is exceedingly difficult to learn what data means. These interpretative steps move the translation to the human level. Another strategy to facilitate finding and sharing information is to organize data or content (esp. documents, articles, etc.) with respect to a taxonomy or classification, as is done in a typical directories. Limitations of having a single taxonomy, the intense manual effort to classify, lack of ability to deal with dynamic data (e.g., those generated using queries to database rather than static HTML pages), makes this a limited solution at best.

Among lexical approaches, the three most prevalent semantic integration approaches explored are attribute equivalence, context and domain definitions, and shared ontology. The first two approaches model data in a database to compare domain, constraints, and operation or combine different ontologies in a single database to evaluate semantic equivalence or more generally, semantic distance or proximity (Sheth, 1992; Larson, 1989; Ouksel, 1994). The work on shared ontologies relied on term definitions and interrelations. These semantic similarity studies are the inroads to semantic similarity assessment which use either a shared ontology or a global ontology.

In computer and geographic information science, research work has gone from lexical translation to finding metrics for evaluating the similarity between ontologies. Rodriquez and Fonseca draw on recent work in linguistics and computer science to provide formalized and logical support for constructing ontologies from lexical analysis. The semantic distance model this research uses is a further development of Rodriquez' work on semantic matching distances (Rodriquez, 2000). It is relevant for working with the variety of geographic scales and level of detail. Fred Fonseca extends matching distances to consider the roles, or purposes, for which information was collected (Fonseca, 2001).

Work in computer science is fundamental to the development of KY-WIN technology, and furthermore is particularly relevant to the improving citizen/government interaction not only by way of theory but through rich examples of successful projects (Ashenhurst, 1996, Weber, 1997). Amit Sheth's work in computer science provides the key technological base for several very large semantic interoperability projects (Kashyap and Sheth, 1997, Sheth, 1996, Kashyap and Sheth, 1996, Sheth, 1997, Sheth and Gala, 1989). In this approach, establishing similarities between ontologies calls for comparing the intensional (contextual) descriptions of the two objects, described in a description logic language that links the semantic and schematic level. Conceptually, semantic integration in this approach consists of two phases. In the first phase objects are identified in different databases that are conceptually similar. In the second phase, the semantic differences are resolved between semantically related objects (Kashyap and Sheth, 1996). These steps take place in the conceptual information space.

The main concept in Sheth's approach is semantic proximity, which uses a declarative language to articulate the definitions of objects, and strong ontological definitions that involve vocabulary, content and structure (Sheth, 1996). The concept of semantic proximity refers to an abstraction or mapping between the domains of two objects. Academics consistently refer to semantics as the similarities between objects, relationships, and context. Through constraints on the context, defined by social, cultural, organizational, or political factors, similarities can be expressed through formalized logic representation. In previous research and projects, Sheth and others recognized the impossibility of encoding all meaning and relationships. Instead, the information space concept extends lexical analysis and other formalized approaches in the support of knowledge discovery process that tightly couples the user-interface with analytical tools. Beginning with declarative ontologies in a knowledge base, it facilitates user interaction through the knowledge base and the metadata and data of the federated databases, or any Web-accessible data or resource (static Web pages, dynamically generated Web pages, and URL accessible file or document of any media). Software agents conduct the actual processing.

3 Citizen/Government Interaction

As the map anecdote in the introduction illustrates, difficulties in citizen/government interactions reflect tensions between the non-formalized knowledge and the formalized knowledge of government and science. We have to deal here with different ontologies and different knowledge representations. Knowledge discovery in the information space can help to ameliorate this situation. By facilitating communication and knowledge discovery, KY-WIN can help articulate different ontologies, social spaces, and social identities of citizen knowledge and represent government data and regulatory activities. KY-WIN will ideally become a means of communication integrated in existing discourse. KY-WIN has to become part of local communities to assure communication of different types of knowledge. Citizen knowledge is after all embedded in a community and the productive activities that people engage in to secure their livelihood. When these activities revolve around the availability of natural resources, the ecological cycles of streams, lakes, wetlands are fundamental parts of the citizen's ontology, or knowledge domain, of a place. This is not just knowledge of the present, but it is deeply social and historical, a process of remembering and learning as much as a record of events. Mainstream environmentalism focused on conservation lacks the concern with every day productive concerns integral to informal economies (Reid, 2000). KY-WIN supports the deep layering of local is the strong foundation for community building, or what Francis Fukuyama refers to as social capital (1995). An important outcome of KY-WIN is the development of technology to support the collection and communication of local knowledges. This is crucial too successfully bridging the gap between informal and formal knowledges–an outcome that we believe is critical to the development of democratic decision-making in digital government.

Key to improving citizen/government interaction is finding ways to respectfully represent multiple forms of knowledge. A key feature of local knowledge is the embedding of different domains of knowledges into a complexly interwoven holistic point of view -- one that is often hard for experts and officials to understand. The ontologies of political culture tend to be holistic, multi-issue, flexible in narrative styles, informal in orientation, oriented to direct political action outside of bureaucratic structures, and characterized by a deeply imbedded sense of local place, history and knowledge. Community knowledge of place embeds the economic, cultural, spiritual/moral and environmental in a concretely known landscape where watershed is inseparable from the community's sense of cultural and historical identity (Taylor, 2001). Ontologies of government agencies are task-driven and formalized to provide for a common measure of equity to avoid subjective bias (Weber, 1997; Rechenmann, 1995).

Support for non-formalized ontologies is crucial to improving citizen/government interactions. Many efforts to cultivate citizen outreach in the 1960s and 1970s failed because of a lack of sensitivity to local cultural-political context. Recent research has identified causes of this failure in a lack of organizational attentiveness to the distinctive semantic structures of citizen communication networks and local knowledges (Taylor-Ide, 2001; Billings, 2000). Impediments to an improved government/citizen partnership can be seen among rural working class in Appalachian communities. A century of inequality has created a civil society which creates disjunction between public institutions (like school systems and formal health systems) that have the resources to mandate care and channel innovation and the local culture and civil society. For instance, in Appalachian working-class communities where wage labor has been erratic and inadequate, most people depend on informal economies e.g., foraging in the forests for ginseng, galax and other marketable non-timber forest products; hunting; small-scale gardens; crafts and extra-market trading, illegal activities. Local ecological knowledge–watersheds, landscapes and biodiversity–is intricately woven into concerns about economic production (how will something affect fishing, gather, hunting, etc.), historical memory (a deep attachment to specific features of the landscape as representing moments of history that can go back centuries), generativity (an attachment to place is seen as a crucial legacy to pass on future generations), self sufficiency (outsiders, especially those with power and money, are viewed with suspicion, because of past oppression, which can only be avoided by holding on to local means of subsistence).

In the last two decades this has lead to a distinctive form of non-government organizations in rural-Appalachia which are distinctively place-based rather than government issue-based organizations. These local groups are concerned with multiple issues in ways which tend to be imbedded in local communities rather than specifically addressing a single issue or problem (Fisher, 1993; Taylor, 2001). KY-WIN provides a new space, an information space, to bring citizens, government officials and scientists together to develop IT tools to assist in bridging them. This requires drawing on existing theoretical models to identify and analyze such points of disjuncture between ontologies, and to identify mechanisms that can link disjoint domains. KY-WIN can make a strong contribution emergent Appalachian “mediating structures”(Couto, 1999 ; Taylor, 2001).

4 Design of an Information Space

KY-WIN will support both citizen/government interaction and government information services through a IT infrastructure that allows individuals and agencies to share and protect their information resources. In this sense, the design is focused on developing an extensible architecture to support the developing KY-WIN. Two state agencies will participate in the first stage of developing KY-WIN. First, the Division of Water (DOW), which will assist in citizen/government activities and project components and be involved in developing information services to support mandates and regulatory responsibilities. Second, the Kentucky Office of Geographic Information (OGI), will also assist with IT and help integrate publically accessible metadata in a metadata clearinghouse. Each agency retains control over their data and can regulate access according to mandates and other administrative concerns.

To improve government information services, the analytical tools and government information services developed for DOW in the project using the agent-based technology, will enhance work with the TEMPO and COMPASS environmental databases in the Division of Environmental Protection. TEMPO is a comprehensive database for all Division of Environmental Protection permitting activities, and COMPASS will provide tools for analysis. For example, in the situation where a staff person has a question about the project they are working on and the enforcement of regulations, KY-WIN will have a means for finding, understanding, and representing the necessary information. Using the browser-based application, a staff-person is able to begin a process of knowledge discovery by either geospatial or other domain attributes, or a combination thereof. A simple question, i.e., "How many discharge permits have been issued on the South Branch of Elkhorn Creek?" would be the inroad to an interactive process that keeps the pesky details of database queries away from the staff person and lets them interact through the virtual clearinghouse with all accessible databases. Software agents process common tasks.

Fig. 1 presents the conceptual architecture for KY-WIN's information space. Theoretically, processing involves three steps. All queries go to the gateway which expands and processes them. The first stage of processing involves deploying an ontology agent to check terms, relationships, and actions in the query against domain ontologies and the knowledge base. The ontology agent returns a response which is passed to the extractor agent. In the next step, the extractor agent goes to sources (URI's) identified by the semantic agent and requests information from each source's export agents. The export agent returns the result to the extractor agent. This separation permits each organization to have control over processing–an important part of guaranteeing agency trust. The extractor agent passes the recovered data to the ontology agent who updates a list of operations and parameters and then collates the data before it is turned over to the browser-based interface for display. The entire process is interactive and these results can be revised, expanded, or discarded by the user.

The ontology agent will largely use prepared semantic proximity lists included in the knowledge base. These lists will be generated by other agents not shown in Fig. 1 for formalized knowledge available from government agencies and other organizations that adhere to standardized documentation. The ontology agent will also have the capability to conduct semantic similarity analysis on an as-needed basis. This is crucial for integrating newly added non-formalized knowledge. The results of each new semantic mapping will not only be transferred to the querying browser, but also copied to the knowledge base and made available for future use.

KY-WIN will also provide access to clearinghouses following FGDC standards. Likewise, KY-WIN will also be connected to the National Spatial Data Infrastructure (NSDI) network of clearinghouses. The public metadata prepared in the KY-WIN project will become part of the this network and the Kentucky Spatial Data Infrastructure (KYSDI), part of a long term commitment to building the NSDI. Already well underway, it has reached notable successes at the Federal level and in states, including Kentucky, which have committed millions of dollars to developing state geographic information infrastructures.

Hierarchies of geographic information contained in the NSDI clearinghouse network and domain specific standards provide a framework for coding geographic information in a standardized format that can be used to help handle the semantic complexities of multiple ontologies. Using OpenGIS standards and Geographic Markup Language, the computational solutions will be interoperable for COTS GIS software and public-domain software. Information, relationships, and behaviors will be coded in XML, RDF, XSD, and GML 2.0. Translator agents enable the transformation of information from these different formats.

The KY-WIN information resources will be initially further extended by drawing on other public domain water information for Kentucky, in addition to clearinghouse operation support, KY-WIN will be populated with STOR-IT and Watershed Watch data for testing. As data becomes available from the Division of Water it will be added. Project staff will prepare XML DTD codebooks for formalized interontological relationships. After completion of the first clearinghouse prototype, a second prototype will be developed with data from the Division of Water to support citizen access and internal operations. Through data protection and access control, sensitive data can be shielded from public access as required by mandate or law.

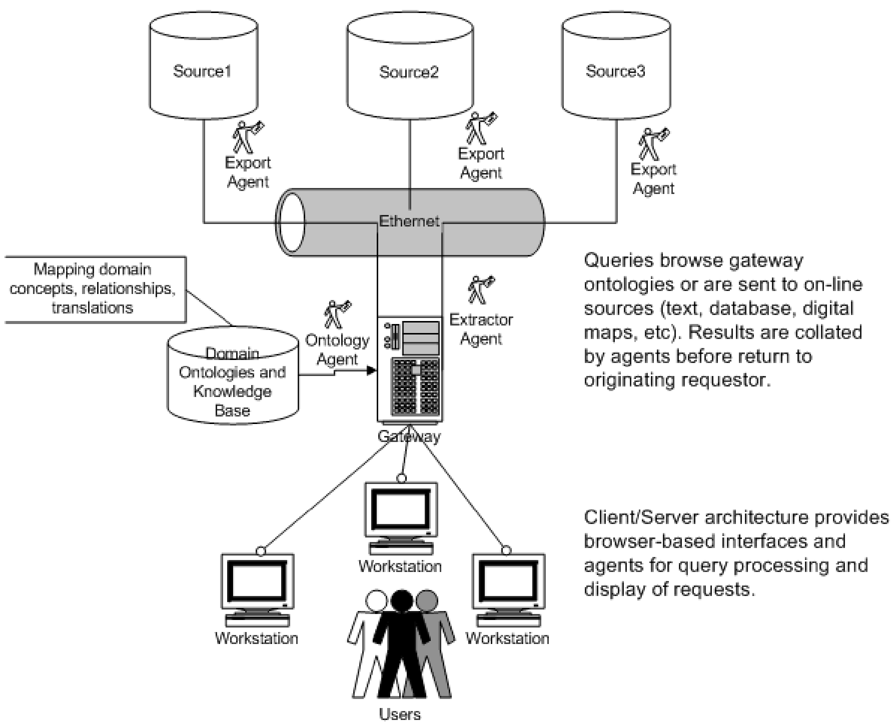

Fig. 1. Conceptual KY-WIN architecture

5 Browser-Based Application and Interface

A key component of KY-WIN is the browser-based application and interface. This software will extend existing public-domain browser technology to support interactive access to multiple information sources, knowledge discovery, geographic visualization, and editing. An operational prototype will be evaluated and refined through a participatory software development process with citizen groups and high school students already engaged in preparing on-line atlases of their areas. Local ontologies of water-related issues will help guide its organization and outlining types of questions and information needs that citizens may raise.

The InformationSpace supports user interaction, knowledge discovery, and learning. It is the interface to incorporate procedural knowledge that the user articulates during interaction and the information that the user brings to the system. For example, a resident of a Cumberland watershed in Harlan county Kentucky may not know at what hierarchy level of the watershed their property is located, but know very well that water only flows through the backyard stream in the winter and spring. This issue calls for extensions of the InformationSpace to incorporate narrative format knowledge and interface techniques to support human needs and capabilities. The project uses participatory design techniques to establish the ontological ideas of citizen group's communities as a basis for human-centered computing and the formalization and implementation of KY-WIN.

The browser will ultimately support natural-language query by parsing queries to keywords and operations that are more readily processed by the ontology agent. The user can respond to the results in an interactive fashion and refine the query through text and geographic visualization in a process of knowledge discovery. The first use of the browser-based application will be closely monitored and protocoled to identify problems and useful strategies that later software revisions should take into account.

Several key features that the browser-based application and interface must support include:

- variable search and selection
- retrieving and managing data
- portable interface layouts and data with transportable profiles
- hybrid text/graphic interface

These features make it possible for people (citizens or staff) to define how broad their search for information should be and have tools for retrieving and managing data on their local computer where the client software is installed. To facilitate exchange and the development of individual ontologies and content, the software will have the functionality to store profiles. This functionality permits any person to access the declarative knowledge of the clearinghouse's knowledge base and complement it with knowledge emerging in the process of discovery. Another key feature of the software will be a combined text/graphic interface that will provide the ability to hyperlink between text and graphic. A person clicking on rivers displayed on a map of Kentucky will see a list of each river's name appear in a text window. This feature will be augmented by using right-click option menus in each window.

6 Semantic Interoperability as Communication

The model presented here for KY-WIN follows concepts aimed at supporting highly diverse users of water-related information. While drawing on previous approaches to semantic interoperability, this model emphasizes the process of knowledge discovery. Software agents, ontologies, knowledge base, and information space support individual people and groups in accessing sources of data and information in the process of generating knowledge.

A contribution of this work to existing concepts of semantic interoperability is the development of a dynamic environment for semantic interoperability. This utilizes concepts, methods, and technologies for formalized knowledges and extends them with the capabilities to support non-formalized knowledges through analytical processes integrated in a browser-based user interface.

The work presented here is at an early stage and the next steps will lead to refinements of concepts and technologies that aid in improving citizen/government interactions.

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